

The Microcirculation and the Lymphatic System

*Functional Parts of the Circulation

It is important to understand the role of each part of the circulation.

1)The function of the arteries is to transport blood under high pressure to the tissues. For this reason, the arteries have strong vascular walls, and blood flowsat a high velocity in the arteries.

2)The arterioles are the last small branches of the arterial system; they act ascontrol conduits through which blood is released into the capillaries. The arteriolehas a strong muscular wall that can close the arteriole completely or canby relaxing, dilate it several fold, thus, having the capability of vastly alteringblood flow in each tissue bed in response to the need of the tissues.

3)The function of the capillaries is to exchange fluid, nutrients, hormones, and other substances between the blood and theinterstitial fluid, To serve this role, the capillary walls are very thin and have numerous minute, capillary pores permeable to water and other small molecular substances.

4)The venules collect blood from the capillaries, and they gradually coalesceinto progressively larger veins.

5)The veins function as conduits for transport of blood from the venules backto the heart; equally important, they serve as a major reservoir of extra blood. Because the pressure in the venous system is very low, the venous walls are thin, they are muscular enough to contract or expand and thereby act as a controllable reservoir for the extra blood, either a small or a large amountdepending on the needs of the circulation.

*The arterioles are highly muscular, and their diameters can change manifold .Themetarterioles (the terminal arterioles) do not have a continuous muscular coat as in arterioles, butsmooth muscle

fibers encircle the vessel at intermittent points.

*The venules are larger than the arterioles and have a much weaker muscular coat, Yet it must be remembered that the pressure in the venules is much less than that in the arterioles, so that the venules still can contract considerably despite the weak muscle.

*Structure of the Capillary Wall

the wall of capillaryis composed ofunicellular layer of endothelial cells and is surroundedby a very thin basement membrane on theoutside of the capillary. The total thickness of the capillarywall is only about 0.5 micrometer. The internaldiameter of the capillary is 4-9 micrometers,large enough for red blood cells and other blood cellsto squeeze through.

Note: the permeability of capillary differs in different tissues, and in each tissues the permeability of capillary gives the function of tissues, forexample:

1)thesinusoids capillary in the liverhave high permeability,that almost all dissolved substances of the plasmaincluding the plasma proteins, can pass from theblood into the liver tissues.

2) the glomerular capillary in the kidney has numeroussmall oval windows called fenestrae ,therefore amounts of very smallmolecular and ionic substances (but not the largemolecules of the plasma proteins) can filter throughthe glomeruli.(renal glomeruli capillary has high permeability for water molecular and electrolytes).

3)the permeability of gastrointestinal capillarymembranes are midway between those of themuscles and those of the liver.

4)In the brain, the junctions between the capillaryendothelial cells are mainly “tight” junctions thatallow only extremely smallmolecules such aswater, oxygenand carbon dioxide to pass into orout of the brain tissues.

**Function of capillary is interchange of water,nutrients,metabolic end product and others substances between the blood and tissues.

Lipid-Soluble Substances Can Diffuse Directly Through the Cell1)

Membranes of the Capillary Endothelium.

If a substance islipid soluble, it can diffuse directly through the cellmembranes of the capillary without having to gothrough the pores.Such substances include oxygen and carbon dioxide.

Because these substances can permeate all areas of the capillary membrane, their rates of transport through the capillary membrane are many times faster than the rates for lipid-insolublesubstances, such as sodium ions and glucose that cango only through the pores.

2)Water-Soluble, Non-Lipid-Soluble Substances.

These substancesdiffuse Only through Intercellular “Pores” or "cleft" in the Capillary Membrane,many substances needed by the tissues are soluble inwater but cannot pass through the lipid membranes ofthe endothelial cells; such substances include water molecules themselves, sodium ions, chloride ions, andglucose.

* There are fourPrimary Hydrostatic and Colloid Osmotic Forcesthat determine the movement of fluid through the capillary membrane, these force are;

1)capillary pressure(PC):which tends to forcefluid outward through the capillary membrane.

2)plasma colloid osmatic pressure(IIp):which tends to cause osmosis of fluid inwardthrough the capillary membrane.

3)interstitial fluid pressure(Pif):which tendsto force fluid inward through the capillarymembrane when Pif is positive but outward whenPif is negative.

4)interstitial fluid colloid osmatic pressure(IIif):which tends to cause osmosis of fluid outward through the capillary membrane.

*Normal Values for Plasma Colloid Osmotic Pressure.

The colloid osmotic pressure of normal human plasmaaverages about 28 mm Hg; 19 mm of this is caused bymolecular effects of the dissolved protein and 9 mm bythe Donnan effect—that is, extra osmotic pressurecaused by sodium, potassium, and the other cationsheld in the plasma by the proteins.

**Donnan effect: large number of positive ions are held near the electrolytes negative charge of plasma protein cause increase the number of osmatic active substances, therefore the plasma colloid osmatic pressure increase from 19mmHg to 28 mmHg.

*Analysis of force Couse filtration and reabsorption in the capillary.

Mean forces tending to move fluid outward.A)

1-Mean capillary pressure. 17.3mmHg

2-Negative interstitial free fluid pressure. 3.0 mmHg

3-Interstitial fluid colloid osmotic pressure.8.0 mmHg

total outward force.28.3 mmHg**

Mean force tending to move fluid inward.B)

1-Plasma colloid osmotic pressure .   28.0 mmHg

total inward force .   28.0 mmHg**

Summation of mean forces**

**Outward 28.3mmHg

Inward28.0mmHg **

net outward force 0.3mmHg

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NOTE: thus for the total capillary circulation, there isnear-equilibrium between the total outward forces28.3mm Hg, and the total inward force, 28.0 mm Hg.

**This slight imbalance of forces, 0.3 mm Hg, causesslightly more filtration of fluid into the interstitialspaces than reabsorption. This slight excess of filtrationis called "net filtration", and it is

the fluid that must bereturned to the circulation through the lymphatic.Thenormal rate of net filtration in the entire body is onlyabout 2 milliliters per minute.(and about((2.88---3)) liter per day).

**Effect of Abnormal Imbalance of Forcesat the Capillary Membrane*

If the mean capillary pressure rises above 17 mm Hg,the net force tending to cause filtration of fluid into thetissue spaces rises.

*20 mm Hg rise in mean capillarypressure causes an increase in net filtration pressurefrom 0.3 mm Hg to 20.3 mm Hg,as a result, fluid will beginto accumulate in the interstitial spaces, and edema will result.

*Extracellular Edema

A large number of conditions can cause fluid accumulationin the interstitial spaces by :

1. A) the abnormal leakingof fluid from the capillaries.

B)preventing the lymphatics from returning fluid from the interstitium backto the circulation.

The following is a partial list of conditionsthat can causeextracellular edema by these twotypes of abnormalities:

1. Increased capillary pressure
2. Excessive kidney retention of salt and water.

1-Acute or chronic kidney failure.

2-Mineralocorticoid excess.

1. High venous pressure and venous constriction.
2. Decreased plasma proteins.

a).abnormalLoss of proteins in urine (nephrotic syndrome).

b).Failure to produce proteins.

. 1-Liver disease (e.g., cirrhosis)

2-Serious protein or caloric malnutrition.

III. Increased capillary permeability.

a). Immune reactions that cause release ofhistamine and other immune products

b). Toxins

c). Bacterial infections

d). Vitamin deficiency, especially vitamin C

e). Prolonged ischemia

1. f) . Burns
2. Blockage of lymph return(obstruction of lymphatic vessels)

a). Cancer

1. b) . Infections (e.g., filarial nematodes{ elephantiasis complication}.

c). Surgery

d). Congenital absence or abnormality oflymphatic vessels.

Lymphatic System

*Essentially all the lymph vessels from the lower partof the body andfrom the left side of the head, the left arm, and left parts of the chest regionempty into the thoracic ductwhich in turn empties into the blood venous system atthe juncture of the left internal jugular vein and left subclavian.

*Lymph from the right side of the neck and head, theright arm, and parts of the right thorax enters the rightlymph duct (much smaller than the thoracic duct),whichempties into the blood venous system at the juncture ofthe right subclavian vein and internal jugular vein.

*Important function of lymphatic system.

1-transports excess fluid from interstitial space to blood circulation.

2-carry excess protein from interstitial space to blood circulation.

3-removeral of bacteria{which do not destroyed in interstitial space} from interstitial space and pass to lymph nodes where the bacteria destroyed.

4-most of fat substances absorbed by small intestinal pass into lymphatic vessels found in intestinal villi.

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Rate of Lymph Flow

any factor that increases interstitialfluid pressure also increases lymph flow if the lymphvessels are functioning normally. Such factors include:

Σ- Elevated capillary pressure.

Σ- Decreased plasma colloid osmotic pressure.

Σ -Increased interstitial fluid colloid osmotic pressure.

Σ- Increased permeability of the capillaries.

*when interstitial fluid volume increase, interstitial fluid pressure also will increase ,which will lead to increase lymph flow. But this relation is not absolute because when the interstitialfluid pressure becomes 1 or 2 millimeters greaterthan atmospheric pressure (greater than 0 mm Hg).

lymph flow fails to rise any further at still higher pressures,This results from the fact that the increasingtissue pressure not only increases entry of fluid intothe lymphatic capillaries but also compresses the outside surfaces of the larger lymphatics{obstruction of lymphatic vessels}cause impedinglymph flow.

Pumping of lymph in lymphatic vessels occurs by:

1)Intrinsic pumping:(internal intermittent or contraction).

when a collecting lymphatic or larger lymph vessel becomes stretched with fluid, the smooth

muscle in the wall of the vessel automatically contracts and causes the fluid to pump through the valve toward the next lymphatic segment, then this segment will stretches, Contracts and pump the lymph through the next valve toward the next segment,the process continuing all along the lymph vessel until the fluid is finally emptied into the blood circulation.

*Note: The lymphatic capillary endothelial cells alsocontain a few contractile acto myosin filaments, these filaments cause rhythmical contraction of the lymphatic capillaries in the same waythat many of the small blood and larger lymphatic vessels also contract rhythmically.

2-External Intermittent Compression:any external factor that intermittently compresses the lymph vessel also can cause pumping, such factors are:

1- Contraction of surrounding skeletal muscles.

2- Movement of the parts of the body.

3- Pulsations of arteries adjacent to the lymphatics.

4- Compression of the tissues by objects outside the body.

هذا عمل طلابي قد لايخلو من الخطأ فالرجاء اعلامنا في حالة وجود خطأ ولاتنسونا من صالح الدعاء

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